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CR- 143257

(E80-10297) INVESTIGATION OF THE
APPLICATION OF HCMM THERMAL DATA TO SNOW
HYDROLOGY Progress Report, Apr. - Jun. 1980
(Environmental Research and Technology,
Inc.) 7 p HC A02/MF A01

N80-30864

Unclassified
CSIL 08L G3/43 00297

INVESTIGATION OF THE APPLICATION OF
HCMM THERMAL DATA TO SNOW HYDROLOGY

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ERT Document No. P-2061-11
HCMM Investigation No. 036

July 1980

Type II Report for Period
April through June 1980

Prepared for

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HCm 036
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1. INTRODUCTION

1.1 Objectives of Investigation

The objectives of the investigation of the application of HCMM thermal data to snow hydrology (HCMM Investigation No. 036) are as follows:

- 1) determine practical utility of HCMM thermal IR data to establish distribution of snow cover and determine accuracy of temperature measurements;
 - a. determine accuracy of surface temperatures acquired through use of HCMM thermal IR measurements,
 - b. determine relative resolution utility between VHRR and HCMM for thermal IR measurements, and
 - c. specifically delineate and quantify the problems involved with measuring snow temperature from space and relate them to present and planned earth observing satellite systems. This objective will take into consideration and utilize the capability of HCMM for day and night thermal measurements over appropriate sites and the satellite's eight-day repeat cycle;
- 2) determine if and how HCMM measurements can be factored in with Landsat data into an overall snow hydrology program related directly to snowmelt runoff prediction; and
- 3) develop an approach to automated data processing of combined visible and thermal infrared satellite acquired data to provide information of interest and use to the snow hydrologist.

1.2 Anticipated Results

The primary anticipated result of the proposed investigation is the development of improved techniques for the mapping and analysis of snow cover using spacecraft-acquired data. The results will provide an evaluation of the usefulness of high resolution thermal infrared data for

snow mapping and for input to snowmelt prediction programs; and will provide a better understanding of the relationships between the measured temperature values and such factors as type of snow, snow depth, type of terrain, and vegetation. The mapping and analysis techniques can then be applied to the automatic processing of data from future spacecraft systems, and will eventually enable snow survey, which is a vital part of water resources management, to be accomplished on a more cost-effective basis.

2. ACCOMPLISHMENTS DURING REPORTING PERIOD

2.1 Data Sample

As reported in the previous progress report, essentially all of the HCMM data needed for the investigation had been received except for some of the day/night registered data for the Sierras study area. During this reporting period, the 12-hour day/night registered data (images and CCT's) for 30 May and 17 July 1978 have been received; the 36-hour registered data for 4-5 April 1979 have also been requested but have not yet been received.

2.2 Data Processing and Analysis

Arizona Study Area

Thermal infrared digital data from the U-2 High Altitude Multispectral Scanner flown over the Arizona study area on 4 April 1979 have been processed for a selected portion of the Salt-Verde Watershed. The data from the daytime flight have been compared with the corresponding HCMM data for that date. The results of the comparative analysis are discussed in Section 7.

Sierras Study Area

The 12-hour and 36-hour ΔT data for the May case have been processed. The ΔT values were subsequently examined for selected snow-covered areas in the southern Sierras, including the more densely forested, lower elevation areas on the western slopes, and the higher elevation, less

densely forested areas in the eastern portion. The results of the analysis are summarized in Section 7. A similar analysis of the day/night registered data for the 17 July case is in progress.

2.3 Atmospheric Corrections

Atmospheric corrections have been computed using radiosonde data for 30 May 1978 and 4 April 1979 from stations in the southwest (in California, Nevada, and Arizona). These corrections were first made using the RADTRA program, supplied by NASA; subsequently, the corrections were also made for selected background temperatures for two sets of radiosonde data using the LOWTRAN program. The computations indicate that for nearly all background temperatures the corrections using the RADTRA program are within 1°K; the corrections using the LOWTRAN program are somewhat greater, but are still within 2°K. Thus, it appears that for the relatively dry atmosphere that is typical over the high elevation snow-covered terrain of central Arizona and the Sierras, the atmospheric corrections to be applied to the HCMM thermal measurements are not significant.

3. PROBLEMS

No problems are anticipated for the remainder of the contract. We anticipate that the investigation can be completed within the revised schedule and meet all originally proposed objectives.

4. PLANS FOR NEXT REPORTING PERIOD

The analysis of the HCMM and supporting data for the two primary study areas (central Arizona mountains and Sierras Nevada in California) will be completed during the next reporting period. All data needed for the analysis, except for the day/night temperature difference data for the April 1979 case, are now on hand. We anticipate that the additional day/night data will be received early in the next reporting period.

We plan to analyze HCMM day/night registered data as well as U-2 High Altitude Multispectral Scanner data for the early April 1979 case for the southern Sierras study area. The HCMM digital data are being processed for 3 April (night), 4 April (night), and 5 April (day);

day/night registered data have been requested for the 36-hour period (4-5 April); the U-2 coverage is for both day and night on 4 April. In addition, we anticipate acquiring special ground-truth data collected for a test site in the Sierras on 6 April 1979. These data, which include surface-based radiometric measurements, were collected as part of a program being carried out by the University of California at Santa Barbara. The ground-truth measurements should provide a means for further calibration of the HCMM data, as well as providing information that will be useful for understanding better the temperatures measured by HCMM over the snowpack.

Preparation of the draft final report will be undertaken during the next reporting period.

5. TRAVEL

During this reporting period, the Principal Investigator attended the HCMM Program Science Review, held at NASA/GSFC on 16-17 June. A presentation of the preliminary results of the investigation was given at the meeting.

6. PUBLICATIONS

No material related to this investigation was published during this reporting period.

7. SIGNIFICANT RESULTS

7.1 Arizona Study Area - Comparison of HCMM and U-2 Daytime Thermal IR Data

The results of the comparison of the thermal IR band temperatures measured by the U-2 High Altitude Multispectral Scanner for a number of locations over the rapidly melting snowcover, with temperatures for these same locations measured on the corresponding daytime HCMM pass, indicate that the U-2 temperatures were typically 5°C higher than the values analyzed from the HCMM thermal infrared digital printout. The following table shows a sample of the temperature differences between the daytime U-2 and the daytime HCMM for the same snow-covered areas.

TABLE 1
HCMM/U-2 COMPARISON FOR ARIZONA STUDY AREA

| Area | Mean HCMM Temperature | Mean U-2 Temperature | Temp. Difference (U-2 minus HCMM) |
|-------------------|-----------------------|----------------------|-----------------------------------|
| A | 0°C | +5°C | +5°C |
| B | -1° | +4° | +5° |
| C | -1° | +4° | +5 |
| D | -2° | +2° | +4 |
| temp at snowline* | +5° | +10° | +5 |

*snowline mapped from visible data

These results tend to substantiate the findings of other investigators that with the offset that has been applied to all HCMM data, based on the early White Sands calibration, the HCMM temperature values may, in fact, actually be 5°C too low.

7.2 Sierras Study Area

In the previous progress report, the results of the analysis of the differences between the HCMM day and night temperatures for selected snow-covered areas derived from the daytime and nighttime printouts were presented. In Table 2, the 12-hour and 36-hour temperature differences derived from the day/night registered data are presented. These results show greater ΔT values for the sparsely vegetated higher elevations than for the lower elevation, more densely forested terrain. The differences for the 12-hour sequence are also greater in most instances than the 36-hour differences. This may be due to the occurrence of higher temperatures overall on the afternoon of 30 May than on 31 May; reported temperature data will be examined further in this regard.

8. FUNDS EXPENDED

Approximately 80 percent of the total available funds for the contract have been expended to date. It is anticipated that the investigation can be completed meeting all originally proposed objectives within the remaining funds and contract schedule.

TABLE 2
HCMM TEMPERATURE DIFFERENCE (ΔT) ANALYSES
FOR SIERRAS STUDY AREA 30 - 31 MAY 1978

| <u>FEATURE</u> | <u>AVERAGE ΔT ($^{\circ}$C)</u> | |
|---|--|--|
| | <u>12 HOUR</u> | <u>36 HOUR</u> |
| 1. MONO LAKE | 5.4 $^{\circ}$ | 2.6 $^{\circ}$ |
| 2. SNOWCOVER IN DENSELY FORESTED, LOWER ELEVATION AREAS ON WESTERN PORTION OF SIERRAS FOR SELECTED POINTS | 7.2 $^{\circ}$ 4.8 $^{\circ}$ 6.5 $^{\circ}$ 6.8 $^{\circ}$ 6.4 $^{\circ}$ | 2.9 $^{\circ}$ 3.6 $^{\circ}$ 2.6 $^{\circ}$ 3.7 $^{\circ}$ 4.8 $^{\circ}$ |
| AVERAGE FOR ALL SELECTED POINTS | 6.3 $^{\circ}$ | 3.5 $^{\circ}$ |
| 3. SNOWCOVER IN SPARSELY FORESTED, HIGHER ELEVATION AREAS ON EASTERN PORTION OF SIERRAS FOR SELECTED POINTS | 9.4 $^{\circ}$ 7.1 $^{\circ}$ 8.7 $^{\circ}$ 8.4 $^{\circ}$ | 9.5 $^{\circ}$ 7.7 $^{\circ}$ 8.3 $^{\circ}$ 8.4 $^{\circ}$ |
| AVERAGE FOR ALL SELECTED POINTS | 8.4 $^{\circ}$ | 8.5 $^{\circ}$ |